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Kinetic and gravitational potential energy worksheet

AQA AS 7407 and first-year A Level 7408 | OCR A AS H156 and A Level H556

35–40 minutes independent practice + 15–20 minutes review | 38 marks

Specification points covered

- AQA 7407 / 7408: 3.4.1.7 selected work–energy links; 3.4.1.8 kinetic energy, uniform-field gravitational energy and full or partial transfers.
- OCR A H156 / H556: 3.3.2(a)–(c), including both first-principles derivations; 3.3.1(c)–(e) selected conservation and transfers. No inverse-square gravity is required.

Mission assumptions

Project Asteria is an asteroid-deflection and sample-return mission. For every stated height change, use the supplied uniform field $g = 0.24\ \text{N kg}^{-1}$. Heights refer to changes in centre-of-mass position.

Treat bodies as particles, neglect rotation and use the stated transfer model. Show calculation working in blank spaces; use ruled lines for written explanations.

1. Deriving the equations from first principles [6 marks]

The mission team checks that its energy model follows from earlier mechanics rather than treating the equations as facts to memorise.

(a) Starting with $W = Fs$, $F = ma$ and $v^2 = u^2 + 2as$, derive $\Delta E_k = \frac{1}{2}m(v^2 - u^2)$. Here F is a constant resultant force on a body of constant mass and W is its net work. Show the algebraic steps. [3 marks]

(b) A payload is lifted through a vertical height Δh at constant speed with negligible resistance. Starting with $W = Fs$ and the weight mg, derive $\Delta E_p = mg\Delta h$. Explain why the lifting work increases gravitational potential energy. [3 marks]

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2. Calibration calculations [5 marks]

Before descent, three systems are checked close to the asteroid surface. Use g = 0.24 N kg^{-1}.

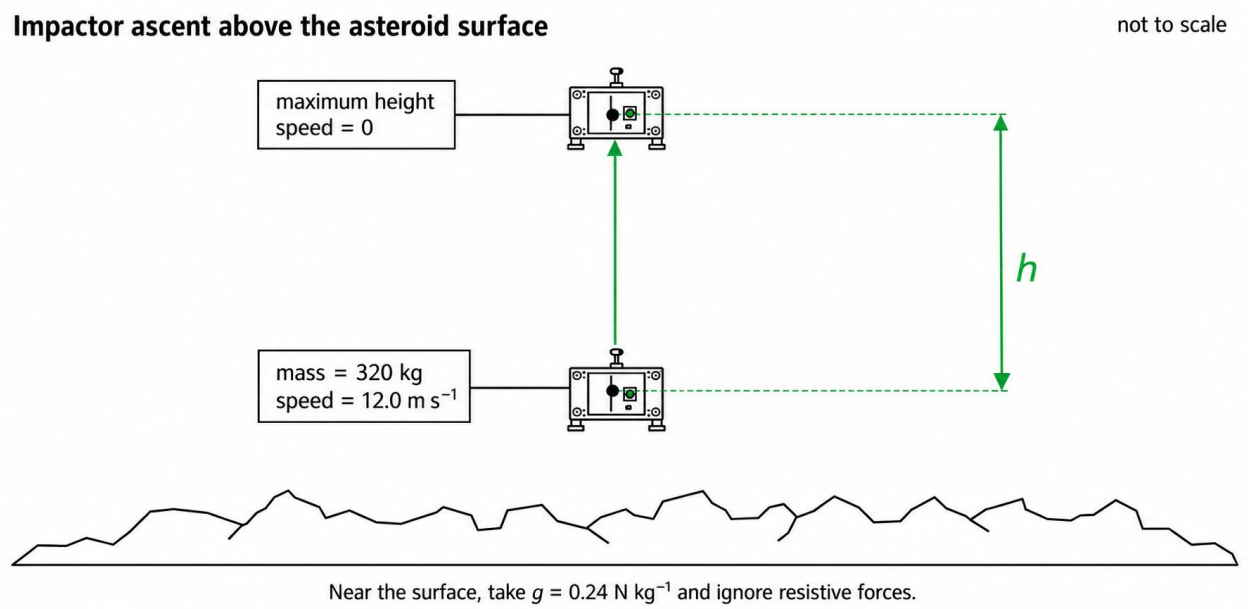
(a) A 24.0 kg mapping drone moves at 6.50 m s^{-1}. Its approach kinetic energy must not exceed 500 J. Calculate its kinetic energy and decide whether this limit is met. [2 marks]

(b) A 27.0 kg inspection unit has kinetic energy 864 J. Calculate its speed. [2 marks]

(c) An 18.0 kg instrument is lifted vertically through 75.0 m. Calculate its increase in gravitational potential energy. [1 mark]

3. A complete energy transfer [4 marks]

A 320 kg kinetic impactor fires its thrusters close to the asteroid surface until it is moving vertically upwards at 12.0 m s^{-1}. Its engines then switch off. Resistive forces are negligible and g = 0.24 N kg^{-1} is uniform.



Near the surface, take g = 0.24 N kg^{-1} and ignore resistive forces.

(a) Calculate the impactor's kinetic energy when the engines switch off. [1 mark]

(b) Calculate the maximum height reached above the switch-off point. [2 marks]

(c) Describe the exchange between kinetic energy and gravitational potential energy as the impactor rises. [1 mark]

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4. Does mass affect the maximum height? [3 marks]

Two sample hoppers have different masses. Both launch vertically upwards from the same point at 9.60 m s^{-1}. Resistive forces are negligible and g = 0.24 N kg^{-1} is uniform.

(a) State which hopper reaches the greater maximum height. [1 mark]

(b) Use the kinetic and gravitational potential energy equations to show that mass cancels, then calculate the maximum height. [2 marks]

5. A tethered canister: partial transfer while rising [4 marks]

A 48.0 kg sample canister leaves the surface vertically at 10.0 m s^{-1}. A magnetic brake on its tether transfers energy to thermal stores. At the highest point, 72% of the initial kinetic energy has increased the gravitational potential energy store. Use g = 0.24 N kg^{-1}.

(a) Calculate the initial kinetic energy of the canister. [1 mark]

(b) Calculate the increase in gravitational potential energy. [1 mark]

(c) Calculate the maximum height reached. [1 mark]

(d) Calculate the energy transferred to thermal stores by the brake. [1 mark]

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6. A landing package: partial transfer while falling [5 marks]

A descent tether brakes a 90.0 kg seismometer package released from rest 160 m above its landing site. Just before contact, 65% of the decrease in gravitational potential energy is kinetic energy. The remainder has been transferred to thermal and internal stores by the tether brake. Use g = 0.24 N kg^{-1}.

(a) Calculate the decrease in gravitational potential energy. [1 mark]

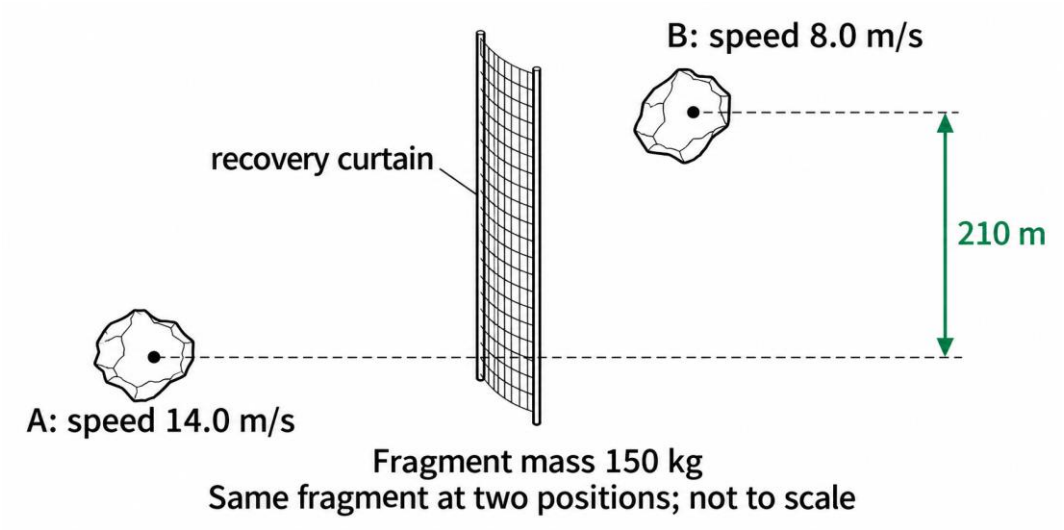
(b) Calculate the kinetic energy just before touchdown. [1 mark]

(c) Calculate the speed just before touchdown. [2 marks]

(d) Calculate the energy transferred to thermal and internal energy stores. [1 mark]

7. Tracking an ejecta fragment [4 marks]

A 150 kg fragment leaves an impact crater at A at 14.0 m s^{-1}. Between A and B it passes through a recovery curtain that exerts resistance. At B it is 210 m higher and moves at 8.0 m s^{-1}. Apart from gravity and this interaction, no other energy transfer occurs. Use g = 0.24 N kg^{-1}.



(a) Calculate the decrease in kinetic energy from A to B. [1 mark]

(b) Calculate the increase in gravitational potential energy from A to B. [1 mark]

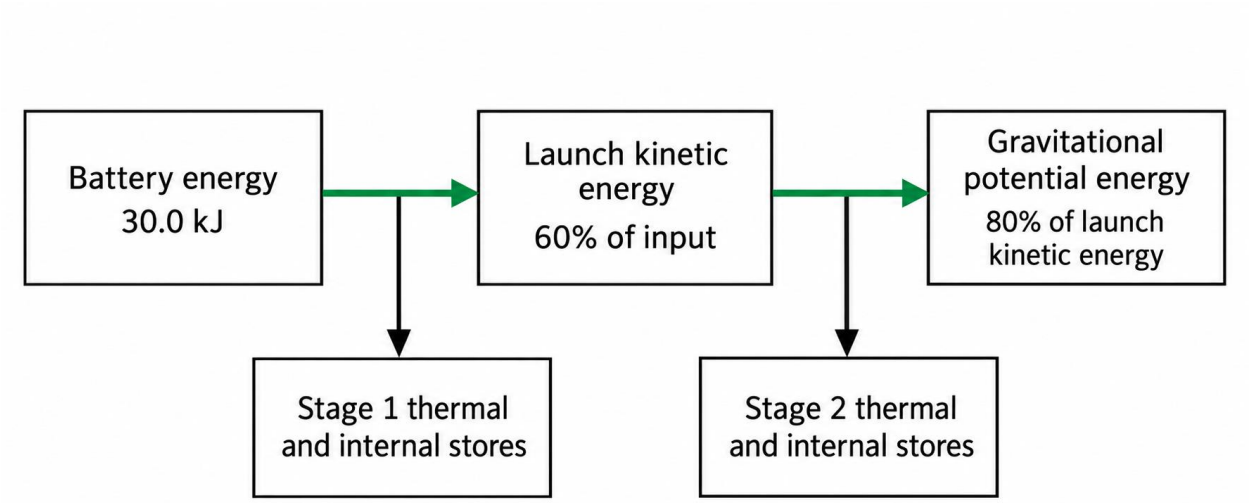
(c) Calculate the energy transferred to other stores between A and B. [1 mark]

(d) Explain why the calculation shows that the transfer from kinetic energy to gravitational potential energy is only partial. [1 mark]

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8. Two-stage sample-return launch [7 marks]

A launcher transfers 30.0 kJ from a battery. In stage 1, 60% becomes kinetic energy of a 120 kg capsule. In stage 2, 80% of that kinetic energy increases its gravitational potential energy. The capsule rises vertically and is momentarily at rest at the end. All other energy is transferred to thermal and internal stores. Use g = 0.24 N kg^{-1}.



Energy transfers; arrows not to scale.

(a) Calculate the kinetic energy of the capsule immediately after launch. [1 mark]

(b) Calculate the launch speed. [2 marks]

(c) Calculate the increase in gravitational potential energy during stage 2. [1 mark]

(d) Calculate the height gained during stage 2. [1 mark]

(e) Calculate the total energy transferred to thermal and internal energy stores across both stages. [1 mark]

(f) Calculate the percentage of the original 30.0 kJ that becomes gravitational potential energy. [1 mark]

Review and improve

□ I can derive $E_k = \frac{1}{2}mv^2$ and $\Delta E_p = mg\Delta h$ from earlier mechanics.
□ I can distinguish a complete transfer from a partial transfer.
□ I can account for energy transferred to thermal and internal stores.

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